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(71) Applicant (*for all designated States except US*): OPTILLION AB [SE/SE]; Box 47646, S-117 94 Stockholm (SE).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): ISHII, Atsushi [JP/SE]; Blåsutvägen 9, S-121 36 Johanneshov (SE).

(74) Common Representative: OPTILLION AB; Box 47646, S-117 94 Stockholm (SE).

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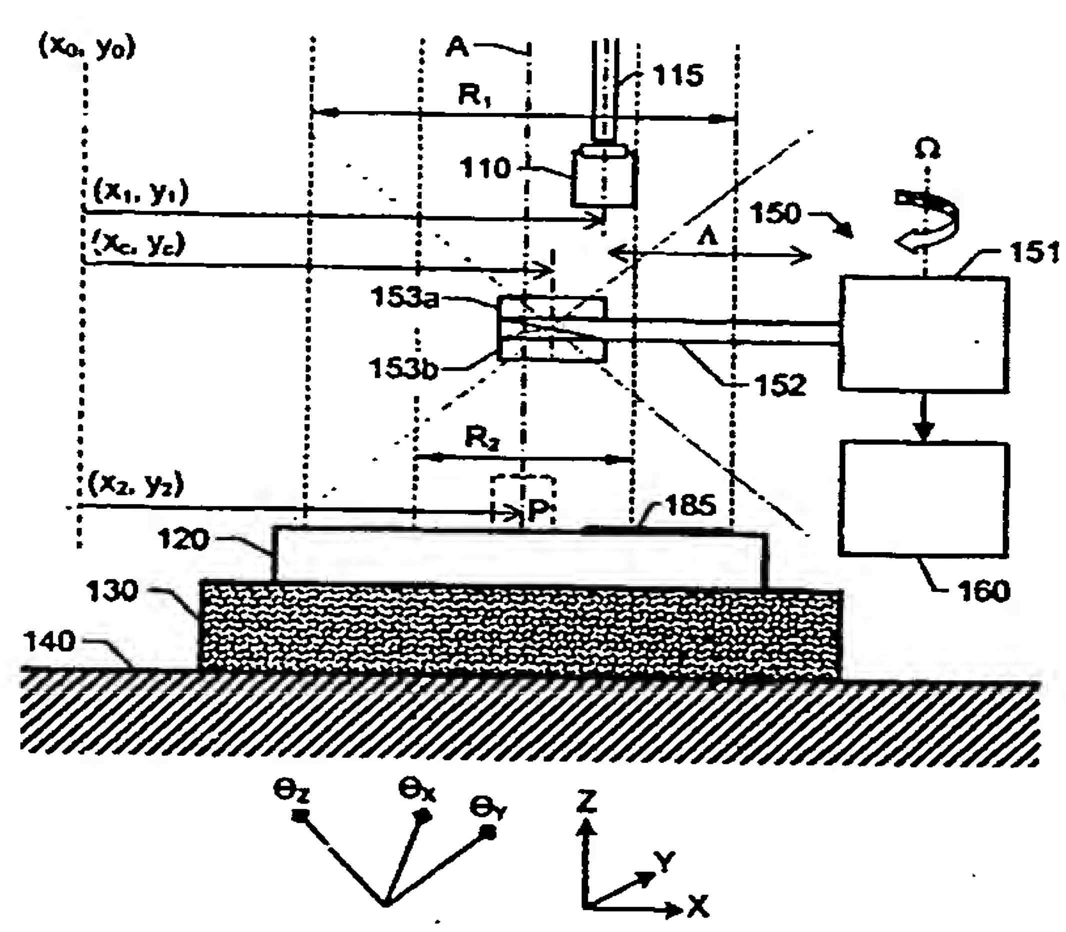
(54) Title: METHOD AND APPARATUS FOR HIGH-ACCURACY PLACING OF AN OPTICAL COMPONENT ON A COMPONENT CARRIER



(57) Abstract: The present invention relates to high-precision placement of optical components (110), such as semiconductor lasers, lenses and photodiodes on component carriers. A first positioning means (115) positions the optical component (110) within a first range of tolerance (R1) with respect to a perpendicular axis (A) from an intended position (P) on the component carrier (120). Then, at least one image representing the optical component (110) and a target area, which includes the intended position (P) are captured (150) and image processed (160). Based on the result of this processing, a second positioning means (140) fine positions the component carrier (120) with respect to the optical component's (110) position relative the axis (A), such that the optical component (110) and the intended position (P) on the component carrier (120) are aligned within a second range of tolerance (R2), which is more narrow than the first range of tolerance (R1). Finally, the first positioning means (115) places the optical component (110) on the component carrier (120).

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Method and apparatus for high-accuracy placing of an optical component on a component carrier

THE BACKGROUND OF THE INVENTION AND PRIOR ART

The present invention relates generally to high-precision placement of semiconductor components, so-called dies, on carriers. More particularly the invention relates to a method of placing an optical component on a component carrier according to the preamble of claim 1 and a corresponding apparatus according to the preamble of claim 13. The invention also relates to a computer program according to claim 11 and a computer readable medium according to claim 12.

In order to accomplish fiberoptical communication devices with high efficiency it is generally important that the included components are placed at their intended positions on the circuit board with very high accuracy. It is especially important that the optical components, such as lasers, lenses and photodiodes in, for example fiberoptical transceivers, are placed within comparatively narrow tolerance ranges on their respective carriers. Otherwise, a substantial amount of the processed optical energy risk being lost due to various geometrical mismatches. For instance, a light ray from a semiconductor laser, which is intended to be received by a single-mode optical fiber may be partially or completely reflected instead of received by the fiber in case the fiber is dislocated with respect to its optimal position in front of the laser. Correspondingly and on similar grounds, only a fraction of the maximum possible light emitted from an optical fiber, which is to be converted into electrical energy via a photodiode may actually reach the photodiode's active area.

It is true that placing the optical components on their carriers with a very high precision might take somewhat longer time to accomplish than to attach them according to a simpler and less accurate manner. However, high-precision placement of the

optical component is likely to render the following manufacture procedure more cost effective, since the requirement for calibrating the components after mounting can be released. For the same reason, maintenance and repair routines can also be made simpler and cheaper. The guaranteed positional relationships between the optical components namely render it possible to replace modules or units completely without or with only a minimum of calibration and trimming. Thus, high-precision placement is desirable for a multitude of reasons.

The known solutions for automatic attachment of electrical components to a circuit board typically involve picking a relevant component from a particular feeder by means of a robot arm, which is movable with respect to six degrees of spatial freedom. Then, the robot arm positions the component approximately above an intended position for the component on the circuit board. After that, the robot arm is fine positioned above this position, e.g. based on image processing. Finally, the robot arm places the component on the circuit board by moving the component vertically towards the board. In most cases, the component is also subsequently soldered to ensure a good electrical contact between the component and the other circuitry on the board.

The above-mentioned robot arm needs to have a relatively long range of movement in order to be capable of both retrieving the components from the feeder and to also place each component on its intended position on the circuit board. In addition to that, it must be possible to control the robot arm with very high accuracy in all six degrees of spatial freedom. This is most commonly represented by linear movement along three mutually perpendicular axes respective rotation around three mutually perpendicular axes. However, a robot with arm which fulfills all these requirements sufficiently well with respect to today's fiberoptical communication systems will be exceedingly expensive and technically very complex. Moreover, such robot would be seriously sensitive to mechanical disturbances and

would hence require frequent calibration.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to provide a solution, which alleviates the problems above and thus makes possible high-precision placement of optical components on a carrier by means of a comparatively simple and reliable robot arm.

According to one aspect of the invention the object is achieved by a method of placing an optical component on a component carrier, as initially described, which is characterized by the step of, based on the result of the image processing and before placing the optical component on the component carrier, fine positioning the component carrier with respect to the optical component's position relative a perpendicular axis from the intended position for the optical component, such that the optical component and the intended position on the component carrier are aligned within a second range of tolerance. This range is presumed to be more narrow than a first range of tolerance within which the optical component is positioned initially, by a first positioning means, such as a robot arm.

An advantage achieved with the above fine positioning of the component carrier is that a relatively simple, robust and yet low-cost robot can be used for retrieving the optical components from the feeder. Yet the components can be positioned very accurately on the carrier.

According to a preferred embodiment of this aspect of the invention, the optical component is placed on the component carrier by linearly moving the optical component along an axis, which is substantially perpendicular to a surface of the component carrier where the intended position is located.

According to another preferred embodiment of this aspect of the

invention, a calibration procedure is performed between repeated placements of optical components on one or more component carriers. This calibration procedure comprises the following steps. Initially, a first calibration component is acquired in place of the optical component. The first calibration component contains a first reference pattern. Then, the first calibration component is positioned within the first range of tolerance with respect to the perpendicular axis from the intended position on the component carrier. Subsequently, a first calibration image representing the first reference pattern is captured from the position between the first calibration component and a second reference pattern, which is located within the target area. A corresponding second calibration image representing the second reference pattern is also captured from the same position. After that, the first and second calibration images are image processed. Finally, based on the image processing, the placing step is calibrated such that an optical component being placed on a component carrier after the calibration procedure is located at least as close to the intended position as an optical component placed on a component carrier before the calibration procedure.

According to a further aspect of the invention the object is achieved by a computer program directly loadable into the internal memory of a computer, comprising software for performing the above proposed method when said program is run on a computer.

According to another aspect of the invention the object is achieved by a computer readable medium, having a program recorded thereon, where the program is to make a computer perform the method proposed in the penultimate paragraph above.

According to yet another aspect of the invention the object is achieved by an apparatus for high-accuracy placing of an optical component on a component carrier as initially described, which

is characterized in that it comprises a second positioning means, which fine positions the component carrier with respect to the optical component's position relative the perpendicular axis from the intended position for the optical component, such that the optical component and the component carrier are aligned within a second range of tolerance, which is more narrow than the first range of tolerance, before the first positioning means places the optical component on the component carrier. The operation of the second positioning means is based on the result of the image processing.

As already indicated, the advantage achieved by the second positioning means is that the first positioning means can be made relatively simple, robust and yet entail a low cost. At the same time, the components can be positioned very accurately on the carrier.

According to a preferred embodiment of this aspect of the invention, the first positioning means is adapted to place the optical component on the component carrier by linearly moving the optical component along an axis, which is substantially perpendicular to a surface of the component carrier where the intended position is located.

According to another preferred embodiment of this aspect of the invention, the second positioning means is adapted to move the component carrier with respect to six spatial degrees of freedom, for instance, by means of a so-called hexapod.

For a given quality level, the proposed solution thereby reduces the manufacture costs for any type of high-precision optical communication equipment.

Moreover, the maintenance and repair routines for the equipment can be made cheaper due to simplified or eliminated calibration requirements for the optical component after attachment.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is now to be explained more closely by means of preferred embodiments, which are disclosed as examples, and with reference to the attached drawings.

Figure 1 schematically shows an apparatus for die attachment according to the invention,

Figure 2 shows a top-view of the component carrier in figure 1,

Figure 3 illustrates a first orientation problem associated with a typical prior-art solution,

Figure 4 illustrates a proposed solution to the problem addressed with reference to figure 3,

Figure 5a illustrates a second orientation problem which is solved according to an embodiment of the invention,

Figure 5b shows a set of calibration images that are captured according to a proposed calibration procedure in order to make possible a compensation for the second orientation problem,

Figure 6 illustrates, by means of a flow diagram, a proposed calibration procedure, and

Figure 7 illustrates, by means of a flow diagram, the general method according to the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Figure 1 shows an apparatus according to an embodiment of the invention for placing an optical component 110 on a component carrier 120, e.g. a semiconductor substrate. The apparatus comprises a first positioning means 115 (for example a robot arm), a second positioning means 140, an image capturing

means 150 and an image processing means 160. Preferably, a soldering oven 130 is attached to the second positioning means 140, such that the optical component 110 can be straight-forwardly soldered to the component carrier 120 after having been positioned there.

In addition to positioning the optical component 110, the first positioning means 115 is preferably used also for retrieving the component 120 from, for instance a component feeder. The first positioning means 115 then positions the optical component 110 within a first range of tolerance R_1 with respect to a perpendicular axis A from an intended position P on the component carrier 120. The first range of tolerance R_1 may be relatively wide. However, the first range of tolerance R_1 must be narrow enough to guarantee that the optical component 110 is visible from a first camera lens 153a of the image capturing means 150. The image capturing means 150 captures a first image of the optical component 110 via the first camera lens 153a and an optical extender 152. Based on information pertaining to a set of offset coordinates x_c, y_c defining the first camera lens' 153a position relative a reference position x_0, y_0 in a plane being substantially parallel to the top surface of the component carrier 120, a first set of offset coordinates x_1, y_1 defining the position of the optical component 110 in a corresponding plane are determined by means of the image processor 160. The image capturing means 150 then captures, via a second camera lens 153b and the optical extender 152, a second image representing a target area T (see figure 2), which includes the intended position P. Analogous to the first set of offset coordinates x_1, y_1 for the optical component 110, a second set of offset coordinates x_2, y_2 for the intended position P is determined by means of the image processor 160 on basis of the second image. The first and second images are captured from a position between the optical component 110 and the component carrier 120. It preferable, however not necessary, that both images are taken from the same position x_c, y_c.

Based on the second set of offset coordinates x_2, y_2 for the intended position P relative the first set of offset coordinates x_1, y_1 for the optical component 110, the second positioning means 140 fine positions the component carrier 120 with respect to the optical component's 110 position relative the axis A, such that the optical component 110 and the component carrier 120 are aligned within a second range of tolerance R_2, i.e. a processor in the apparatus, for instance shared with the image processor 160, calculates an offset difference x_1-x_2, y_1-y_2 between the optical component's 110 offset coordinates x_1, y_1 and the intended position P's offset coordinates x_2, y_2. The fine positioning of the second positioning means 140 then compensates for this offset difference x_1-x_2, y_1-y_2.

The second range of tolerance R_2 should be as narrow as possible and it is presumed to at least be narrower than the first range of tolerance R_1. When the optical component 110 thus has been positioned within the second range of tolerance R_2, the component 110 can be placed on the carrier 120. However, since the camera lenses 153a; 153b and/or the optical extender 152 may be located between the optical component 110 and the component carrier 120 and also in line with the intended path of the first positioning means 115, these image capturing parts must first be removed. This can be accomplished by a linear movement of the relevant parts along at least one axis Λ and/or pivoting around at least one axis Ω. Finally, a processor (not shown) generates a control signal, which controls the first positioning means 115, such that it places the optical component 110 on the component carrier 120 sufficiently close to the intended position P.

According to a preferred embodiment of the invention, the first positioning means 115 places the optical component 110 on the component carrier 120 by moving the component 110 linearly along an axis Z, which is substantially perpendicular to the surface of the carrier 120 where the intended position P is located.

According to another preferred embodiment of the invention, the second positioning means 140 is adapted to move the component carrier 120 and any soldering oven 130 with respect to six spatial degrees of freedom. Such movement is preferably represented by means of linear movement along a first set of three mutually perpendicular axes X, Y and Z respective a pivoting movement around a second set of three mutually perpendicular axes Θ_X, Θ_Y, and Θ_Z. The first set of axes X, Y; Z and the second set of axes Θ_X, Θ_Y ; Θ_Z may, but need not, coincide and hence accomplish a totally free spatial movement. The second positioning means 140 does thus preferably include a hexapod.

It is furthermore advantageous if also the first positioning means 115 is adapted to move the optical component 110 with respect to six spatial degrees of freedom.

Figure 2 shows a top-view of the component carrier 120 in figure 1. According to a preferred embodiment of the invention, a reference pattern 185 is included in the target area T, such that this pattern 185 may be captured in the second image of the intended position P (see also figure 1). Depending on how the image of the reference pattern 185 is distorted relative a non-distorted reference pattern, the component carrier's 120 orientation relative the second camera lens 153b can be determined. A reference pattern 185 may alternatively, or additionally, be located on the top surface of the soldering oven 130, such that any misalignments of this surface with respect to its desired orientation also can be compensated for. Naturally, any design of the reference pattern 185 different from the specific pattern shown in the figure 2 is equally well conceivable as long as the type and degree of distortion can be used to determine the orientation of the component carrier 120 respective the soldering oven 130.

The reference pattern 185 can be further used for calibration purposes. A proposed calibration procedure for the apparatus

will be discussed below with reference to the figures 4 – 5b.

First, however, a problem being associated with a prior-art solution will be discussed with reference to figure 3.

It has been common practice to use an image capturing means 150, such as a camera, that simultaneously captures an image of both the component 110 and the carrier 120 onto which the component 110 is to be placed. By studying a superposition of these images it is then possible to determine how the arm 115 should be moved in order to place the component 110 above an intended position P on the carrier 120. This solution typically presupposes that the image capturing means 150 has an image capturing angle, which is perpendicular against the carrier 120, such that the component 110 can be placed correctly onto the carrier 120 by moving the component 110 perpendicularly along an axis Z towards the carrier 120 from a position where the images of the component 110 and the intended position P superimpose each other perfectly.

Nevertheless, if the image capturing means 150 unintentionally should become tilted by an angle α with respect to its ideal orientation, such that instead of pointing perpendicularly towards the carrier 120 its lenses point along a line A', which is not perpendicular against the surface of the carrier 120, then the component 110 will be placed at a position P' beside the intended position P. Of course, the larger the angle α is, the larger the lateral dislocation will be.

According to an embodiment of the invention, the problem addressed with reference to figure 3 above is solved by capturing two separate images. Figure 4 shows an image capturing means 150, which is located between an optical component 110 and a component carrier 120 and that, in similarity to figure 3, is tilted by an angle α with respect to its ideal orientation. The image capturing means 150 here captures a first image including the component 110 and a first reference

marker 401, which is located at a known position, defined by a set of coordinates x_0, y_0. The image capturing means 150 then captures a second image including a target area where the intended position P is located. The second image also includes a second reference marker 402, which in similarity to first reference marker 401, also is located at a known position. This position may, but need not, be defined by the same set of coordinates x_0, y_0 as the first reference marker 401. Figure 4 illustrates the generation of the two separate images by means of a first arrow ① and a second arrow ② respectively from the lenses 153a and 153b in the image capturing means 150.

Based on the first reference marker's 401 position in the first image relative the optical component 110, the image processor may determine a first set of offset coordinates x_1, y_1 defining the position of the optical component 110. Correspondingly, the image processor may determine a second set of offset coordinates x_2, y_2 defining the position of the intended position P on basis of the second reference marker 402.

With knowledge of any offset difference $x_1 - x_2$, $y_1 - y_2$ between the first set of offset coordinates x_1, y_1 and the second set of offset coordinates x_2, y_2 the placement operation can be adjusted, such that the first positioning means 115 moves the optical component 110 towards the intended position P on the carrier 120, for instance along an axis Z being perpendicular to the top-surface of the carrier 120. This can be accomplished either by offsetting the first positioning means 115, or more preferably, by fine positioning the second positioning means, such that the intended position P becomes located along an axis A between the component 110 and the carrier 120, which is perpendicular to the top-surface of the carrier 120. The latter alternative is illustrated by means of an arrow and a dashed rectangular box in figure 4.

Figure 5a illustrates a second orientation problem, which is solved according to an embodiment of the invention. Ideally,

before placing the optical component 110 on the component carrier 120, the component 110 and the carrier 120 should be oriented such that their respective contact surfaces are parallel to each other.

However, due to, for example calibration errors or mechanical imperfections, both the first positioning means and the second positioning means may unintentionally be more or less tilted. Thus, instead of being oriented along an axis A being perpendicular to a bottom-surface of the optical component, the first positioning means 115 may be oriented with a first angle of orientation $\beta^1_{x,y}$ to the axis A. Correspondingly, the second positioning means may be oriented with a second angle of orientation $\beta^2_{x,y}$ to the axis A, such that a vertical axis from the first positioning means 115 is not perpendicular to the top-surface of the component carrier 120.

According to this embodiment of the invention, any first $\beta^1_{x,y}$ or second $\beta^2_{x,y}$ angle of orientation is compensated for by means of a calibration procedure, which is repeated after having placed one or more optical components on their respective component carriers. The calibration procedure may thus either be performed at certain intervals, say between every 30th component, or whenever it is found necessary (e.g. with indication by an alarm or a supervision signal).

The procedure starts with the first positioning means 115 acquiring a first calibration component 170 in place of the optical component. The first calibration component 170 is here presumed to contain a first reference pattern 175. Then, the first positioning means 115 positions the first calibration component 170 within the first range of tolerance R_1 with respect to the perpendicular axis A from the intended position P on the component carrier 120. After that, the image generating means 150 captures, from the position between the first calibration component 170 and the component carrier 120, a first calibration image representing the first reference pattern 175.

The image generating means 150 also captures a second calibration image representing a second reference pattern 185, which is located within the target area T (which in addition to the second reference pattern 185 includes the intended position P). Figure 5b shows a conventionalized form of the first calibration image 501 and the second calibration image 502.

As can be seen in figure 5b, both the reference patterns 175 and 185 are distorted somewhat in the images 501 and 502 in comparison to a non-distorted reference pattern, such as the pattern 185 shown in figure 2. Based on the type and degree of this distortion, the angles of orientation with respect to the axis A can be determined. More precisely, the first angle of orientation $\beta^1_{x,y}$ between the first calibration component 170 and the axis A can be estimated based on a type and degree of distortion of the first reference pattern 175 in the first calibration image 501 with respect to a first non-distorted reference pattern. Correspondingly, the second angle of orientation $\beta^2_{x,y}$ between the component carrier 120 and the axis A can be estimated based on a type and degree of distortion of the second reference pattern 185 in the second calibration image 502 with respect to a second non-distorted reference pattern.

Thus, the image processor receives the first calibration image 501 and the second calibration image 502, processes the images, and basis on the result thereof, calibrates the placing step in the proposed component-placing method, such that an optical component 110 being placed on a component carrier 120 after the calibration procedure is located at least as close to the intended position P as an optical component 110 was placed on a component carrier 120 before performing the calibration procedure. For example, the placing step may be calibrated by tilting the component carrier 120 by an angle, which compensates for the differences between the first angle of orientation $\beta^1_{x,y}$ and the second angle of orientation $\beta^2_{x,y}$. Figure 5a shows such compensation via an arrow and a dashed box.

Figure 6 illustrates the calibration procedure by means of a flow diagram. A first step 610, positions a first calibration component within a first range of tolerance R_1 with respect to a perpendicular axis from an intended position P on the component carrier. Then, a step 620 captures a first calibration image of the optical component from an input lens position between the optical component and the component carrier. Subsequently, a step 630 captures a second calibration image of a target area T, which includes a second reference pattern, from the same input lens position. The second reference pattern is preferably identical to the first reference pattern. However, this need not be the case.

A following step 640 image processes the first calibration image and the second calibration image. Based on the result of this processing, a step 650 calibrates the proposed placing step (see step 760 in figure 7), such that a future optical component will be placed onto its component carrier more accurately, or at least as accurately as before performing the calibration procedure (in case the placing step was already well calibrated).

Naturally, all of the process steps, as well as any sub-sequence of steps, described with reference to the figure 6 above may be carried out by means of a computer program being directly loadable into the internal memory of a computer, which includes appropriate software for performing the necessary steps when the program is run on a computer. The computer program can likewise be recorded onto arbitrary kind of computer readable medium.

In order to sum up, the general method according to the invention will now also be described with reference to a flow diagram in figure 7.

A first step 710, positions the optical component within a first range of tolerance R_1 with respect to a perpendicular axis from an intended position P on the component carrier 120. Then, in a

step 720, a first image representing the optical component is captured from an input lens position between the optical component and the component carrier. Subsequently, in a step 730, a second image representing a target area T that includes the intended position P is captured from the same input lens position.

A following step 740 image processes the first image and the second image. Based on the result of the image processing, a step 750 fine positions the component carrier with respect to the optical component's position relative the perpendicular axis, such that the optical component and the intended position on the component carrier are aligned within a second range of tolerance R_2, which is more narrow than the first range of tolerance R_1. Finally, a step 760 places the optical component on the component carrier, at least implicitly on basis of the image processing.

In analogy with the calibration procedure described with reference to figure 6 above, all of the process steps, as well as any sub-sequence of steps, described with reference to figure 7 may likewise be carried out by means of a computer program being directly loadable into the internal memory of a computer, which includes appropriate software for performing the necessary steps when the program is run on a computer. The computer program can likewise be recorded onto arbitrary kind of computer readable medium.

The term "comprises/comprising" when used in this specification is taken to specify the presence of stated features, integers, steps or components. However, the term does not preclude the presence or addition of one or more additional features, integers, steps or components or groups thereof.

The invention is not restricted to the described embodiments in the figures, but may be varied freely within the scope of the claims.

Claims

1. A method of placing an optical component (110) with high accuracy on a component carrier (120), comprising the steps of:

positioning the optical component (110) within a first range of tolerance (R_1) with respect to a perpendicular axis (A) from an intended position (P) on the component carrier (120),

capturing, from a position (x_c, y_c) between the optical component (110) and the component carrier (120), at least one image representing the optical component (110) and a target area (T) which includes the intended position (P),

image processing the at least one image, and

placing the optical component (110) on the component carrier (120) on basis of the result of the image processing,

characterized by the step of

based on the result of the image processing and before placing the optical component (110) on the component carrier (120), fine positioning the component carrier (120) with respect to the optical component's (110) position relative the axis (A) such that the optical component (110) and the intended position (P) on the component carrier (120) are aligned within a second range of tolerance (R_2) which is more narrow than the first range of tolerance (R_1).

2. A method according to claim 1, **characterized by** placing the optical component (110) on the component carrier (120) by linearly moving the optical component (110) along an axis (Z) which is substantially perpendicular to a surface of the component carrier (120) where the intended position (P) is located.

3. A method according to any one of the claims 1 or 2, **characterized by** the fine positioning step involving moving the component carrier (120) with respect to six spatial degrees of freedom.

4. A method according to any one of the preceding claims, **characterized by** the fine positioning step involving linear movement of the component carrier (120) along three mutually perpendicular axes (X, Y, Z) respective pivoting the component carrier (120) around three mutually perpendicular axes (Θ_X, Θ_Y, Θ_Z).

5. A method according to any one of the preceding claims, **characterized by** the capturing step involving

capturing a first image representing the optical component (110), and

capturing a second image representing the target area (T).

6. A method according to claim 5, **characterized by** the image processing step further involving

assigning to the first image a first set of offset coordinates (x_1, y_1) relative a reference position (x_0, y_0),

assigning to the second image a second set of offset coordinates (x_2, y_2) relative the reference position (x_0, y_0), and

calculating an offset difference (x_1-x_2, y_1-y_2) between the first set of offset coordinates (x_1, y_1) and the second set of offset coordinates (x_2, y_2).

7. A method according to claim 6, **characterized by** the fine positioning step compensating for the offset difference (x_1-x_2, y_1-y_2).

8. A method according to any one of the preceding claims, **characterized by** a calibration procedure being performed between repeated placement of optical components on one or more component carriers, the calibration procedure comprising the steps of:

acquiring a first calibration component (170) in place of the optical component (110), the first calibration component (170) containing a first reference pattern (175),

positioning the first calibration component (170) within the

first range of tolerance (R_1) with respect to the perpendicular axis (A) from the intended position (P) on the component carrier (120),

capturing, from the position (x_c, y_c) between the first calibration component (170) and a second reference pattern (185) which is located within the target area (T), a first calibration image (501) representing the first reference pattern (175) and a second calibration image (502) representing a second reference pattern (185),

image processing the first calibration image (501) and the second calibration image (502), and on basis thereof

calibrating the placing step such that an optical component (110) being placed on a component carrier (120) after the calibration procedure is located at least as close to the intended position (P) as an optical component (110) placed on a component carrier (120) before the calibration procedure.

9. A method according to claim 8, **characterized by** the image processing involving

estimating a first angle of orientation ($\beta^1{}_{x,y}$) between the first calibration component (170) and the axis (A) based on a type and degree of distortion of the first reference pattern (175) in the first calibration image (501) with respect to a first non-distorted reference pattern,

estimating a second angle of orientation ($\beta^2{}_{x,y}$) between the component carrier (120) and the axis (A) based on a type and degree of distortion of the second reference pattern (185) in the second calibration image (502) with respect to a second non-distorted reference pattern.

10. A method according to any one of the preceding claims, **characterized by** the optical component (110) including at least one of a semiconductor laser, a lens and a photodiode.

11. A computer program directly loadable into the internal memory of a computer, comprising software for performing the

steps of any of the claims 1 – 10 when said program is run on the computer.

12. A computer readable medium, having a program recorded thereon, where the program is to make a computer perform the steps of any of the claims 1 – 10.

13. An apparatus for high-accuracy placing of an optical component (110) on a component carrier (120), comprising

a first positioning means (115)

positioning the optical component (110) within a first range of tolerance (R_1) with respect to a perpendicular axis (A) from an intended position (P) on the component carrier (120), and

placing the optical component (110) on the component carrier (120) on basis of a control signal,

image capturing means (150) capturing, from a position (x_c, y_c) between the optical component (110) and the component carrier (120), at least one image representing the optical component (110) and a target area (T) which includes the intended position (P), and

an image processor (160) image processing the at least one image, and based on the result thereof generating the control signal, **characterized in that** it comprises

a second positioning means (140) fine positioning the component carrier (120) with respect to the optical component's (110) position relative the axis (A) such that the optical component (110) and the intended position (P) on the component carrier (120) are aligned within a second range of tolerance (R_2) which is more narrow than the first range of tolerance (R_1) before the first positioning means (115) places the optical component (110) on the component carrier (120), the operation of the second positioning means (140) being based on the result of the image processing.

14. An apparatus according to claim 13, **characterized in that** the first positioning means (115) is adapted to place the optical

component (110) on the component carrier (120) by linearly moving the optical component (110) along an axis (Z) which is substantially perpendicular to a surface of the component carrier (120) where the intended position (P) is located.

15. An apparatus according to any one of the claims 13 or 14, **characterized in that** the second positioning means (140) is adapted to move the component carrier (120) with respect to six spatial degrees of freedom.

16. An apparatus according to any one of the claims 13 - 15, **characterized in that** the second positioning means (140) is adapted to move the component carrier (120) linearly along three mutually perpendicular axes (X, Y, Z) and to pivot the component carrier (120) around three mutually perpendicular axes (Θ_X, Θ_Y, Θ_Z).

17. An apparatus according to any one of the claims 13 - 16, **characterized in that** the image capturing means (150) is adapted to

capture a first image representing the optical component (110), and

capture a second image representing the target area (T).

18. An apparatus according to claim 17, **characterized in that** the image processor (160) is adapted to

receive the first image and the second image,

assign a first set of offset coordinates (x_1, y_1) relative a reference position (x_0, y_0) to the first image,

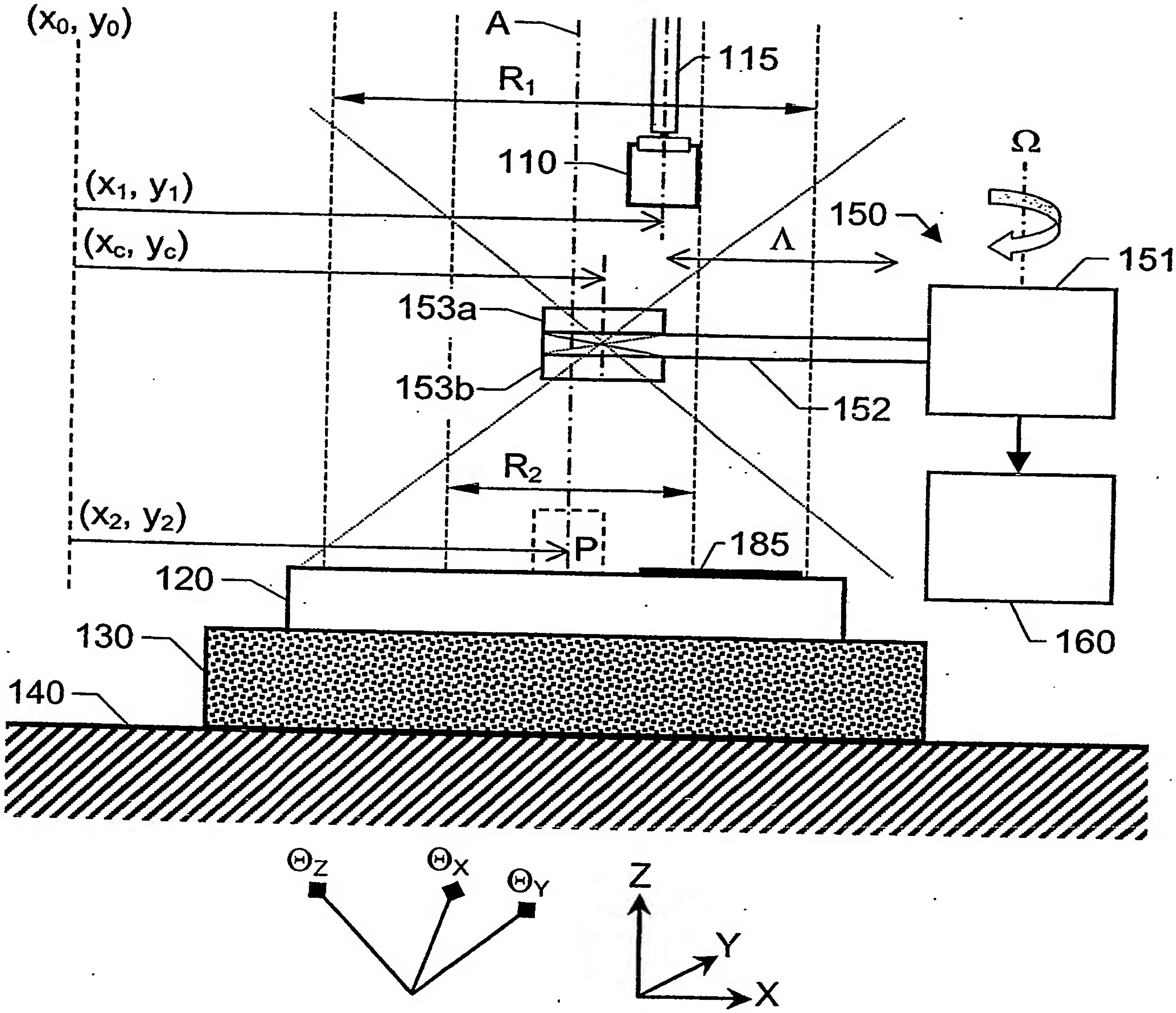
assign a second set of offset coordinates (x_2, y_2) relative the reference position (x_0, y_0) to the second image, and

calculate an offset difference (x_1-x_2, y_1-y_2) between the first set of offset coordinates (x_1, y_1) and the second set of offset coordinates (x_2, y_2).

19. An apparatus according to claim 18, **characterized in that** the second positioning means (140) is adapted to position the

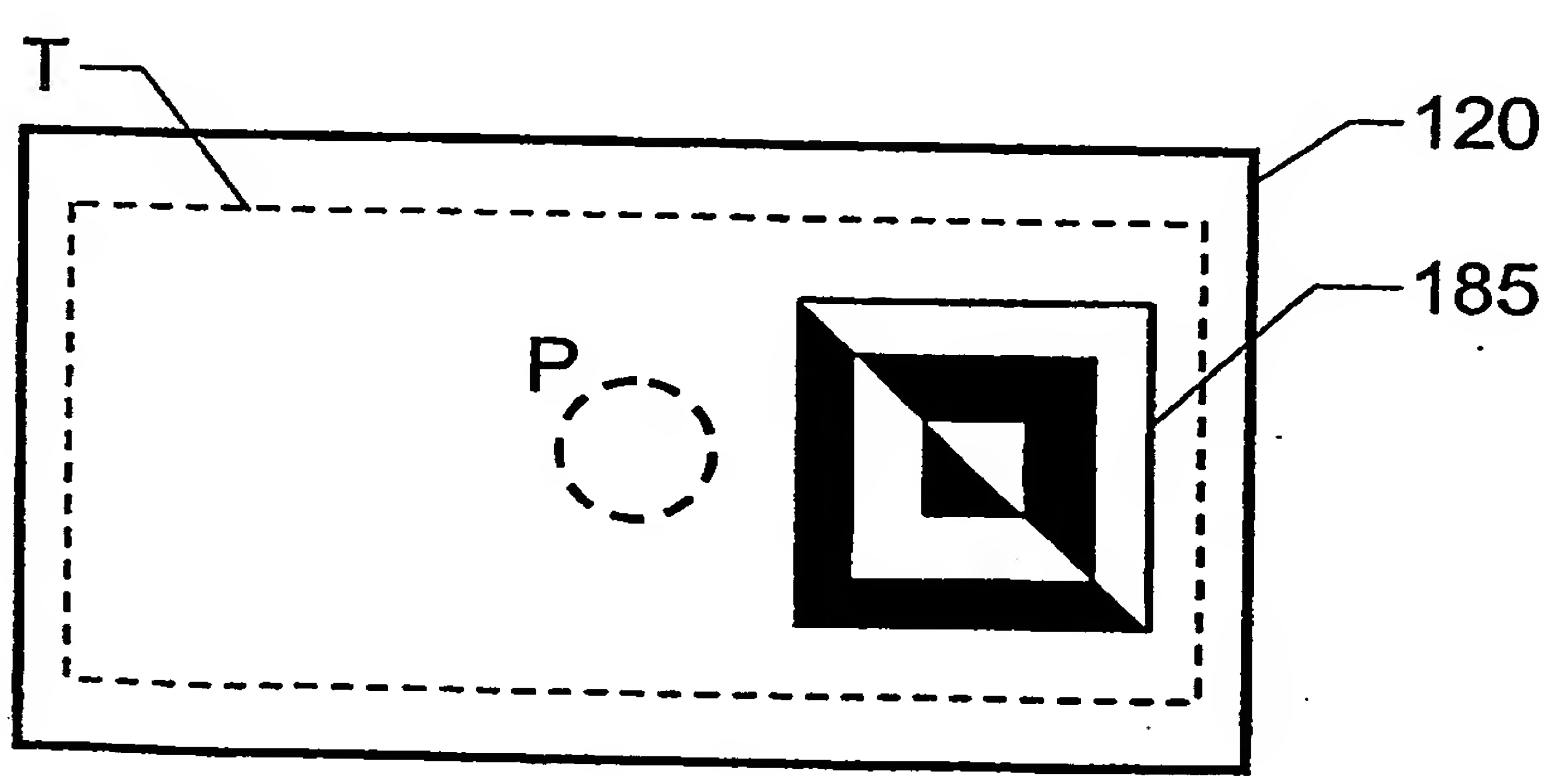
component carrier (120) such that the offset difference (x_1-x_2, y_1-y_2) is compensated.

20. An apparatus according to any one of the claims 13 - 19, **characterized in that** the optical component (110) includes at least one of a semiconductor laser, a lens and a photodiode.



(x0, y0)
A
115
R1
110
(x1, y1)
(xc, yc)
Λ
150
Ω
151
153a
153b
152
R2
(x2, y2)
P
185
120
160
130
140
ΘZ
ΘX
ΘY
Z
Y
X

Fig. 1



T
120
185
P

Fig. 2

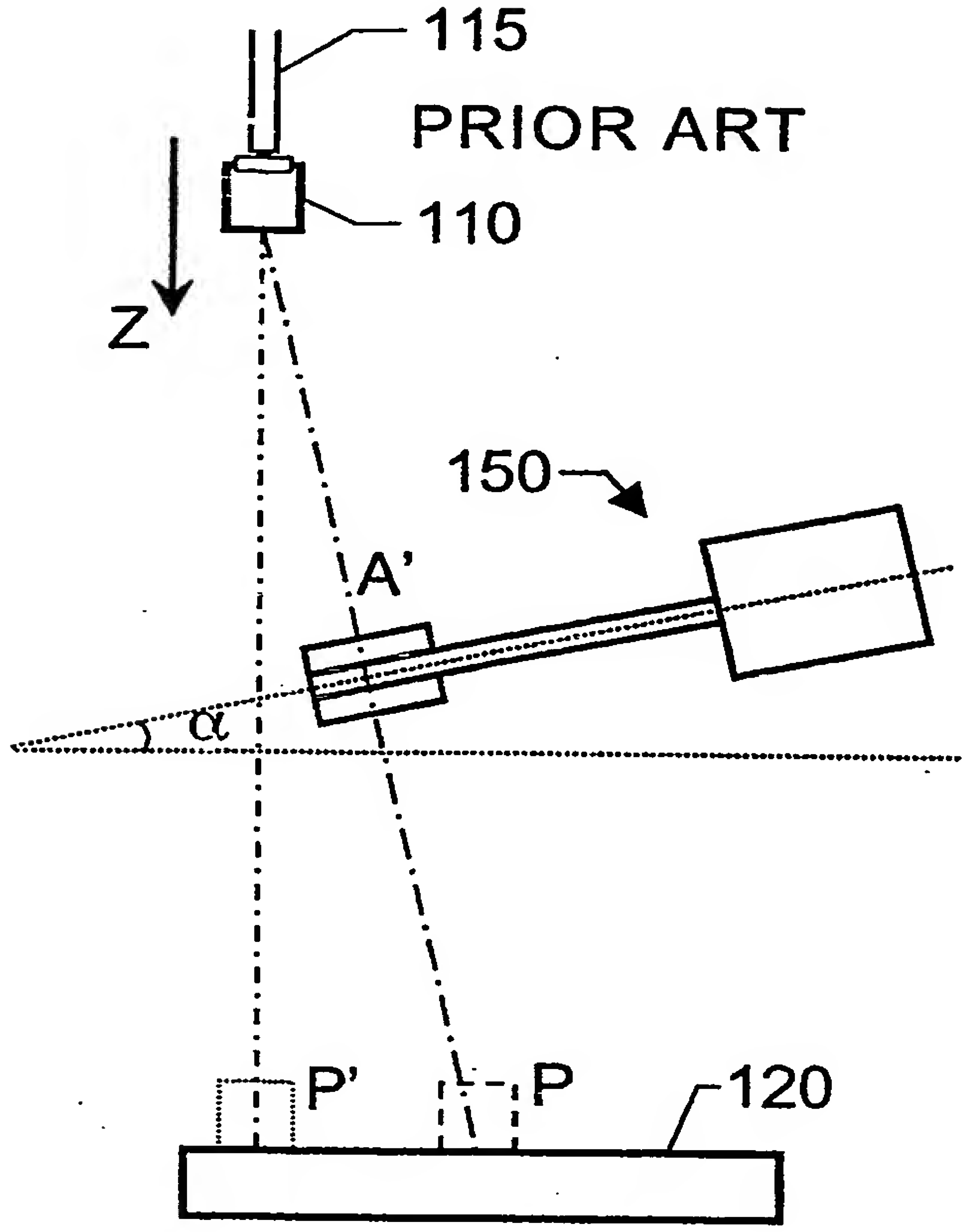


Fig. 3

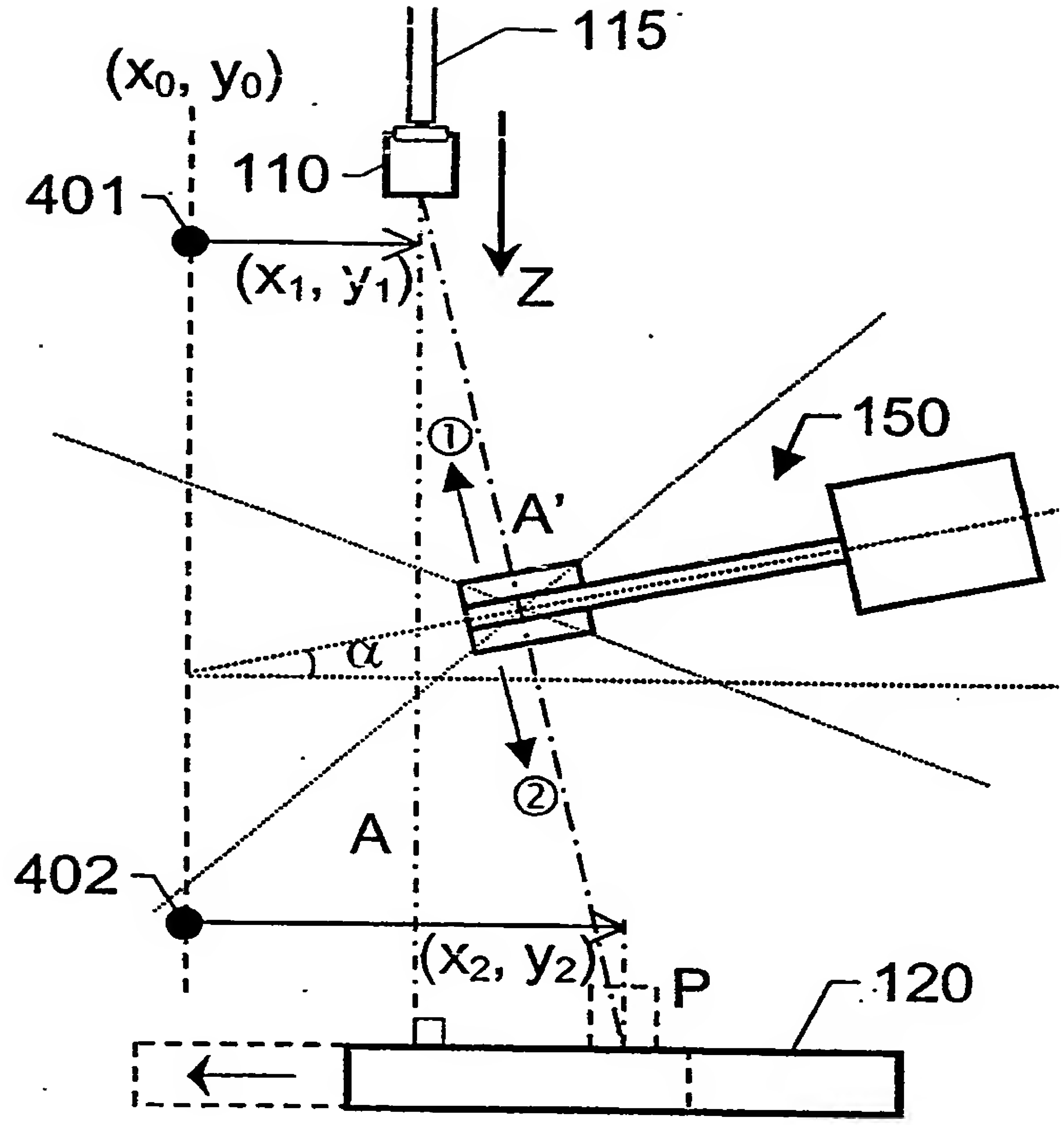


Fig. 4

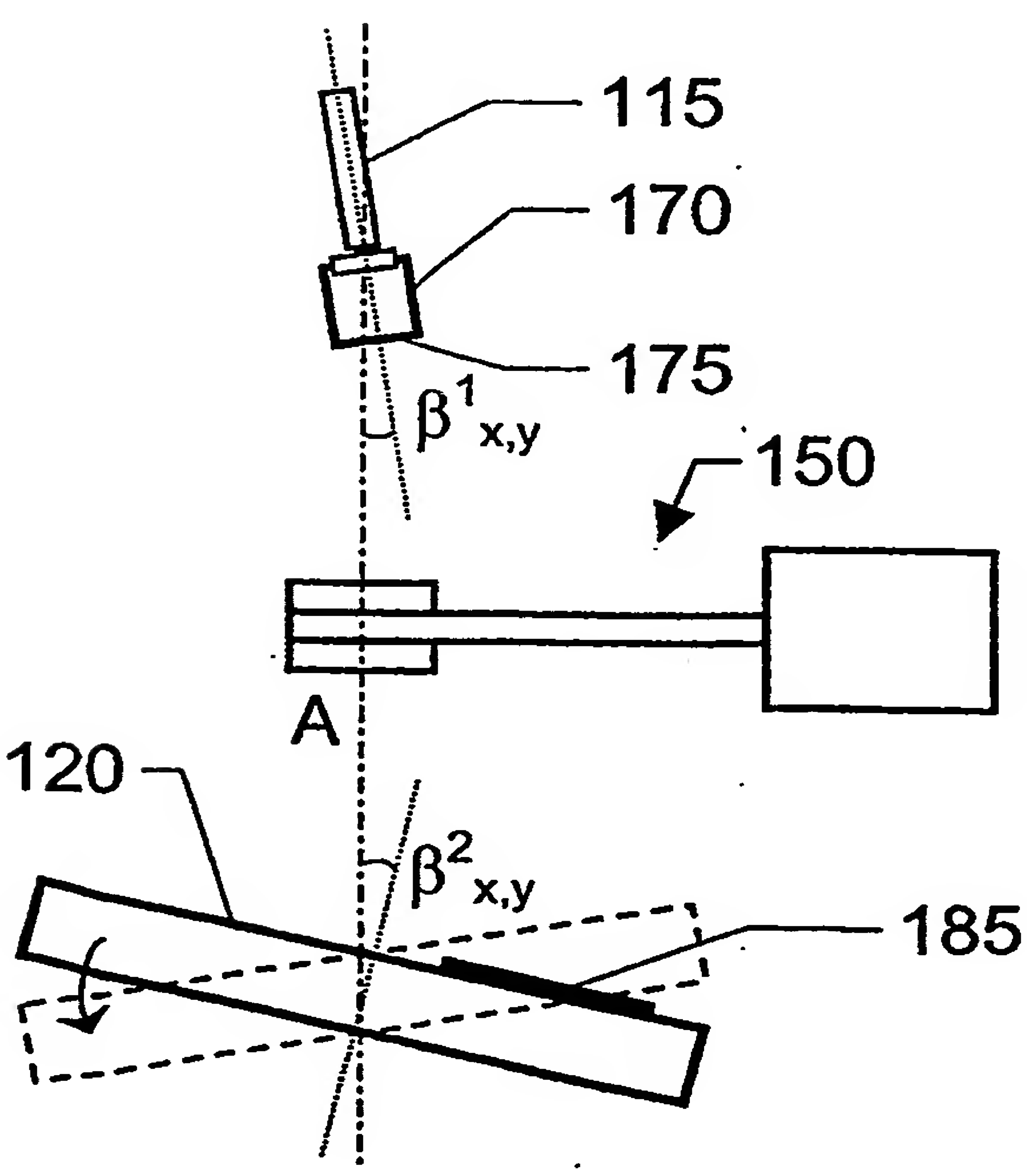


Fig. 5a

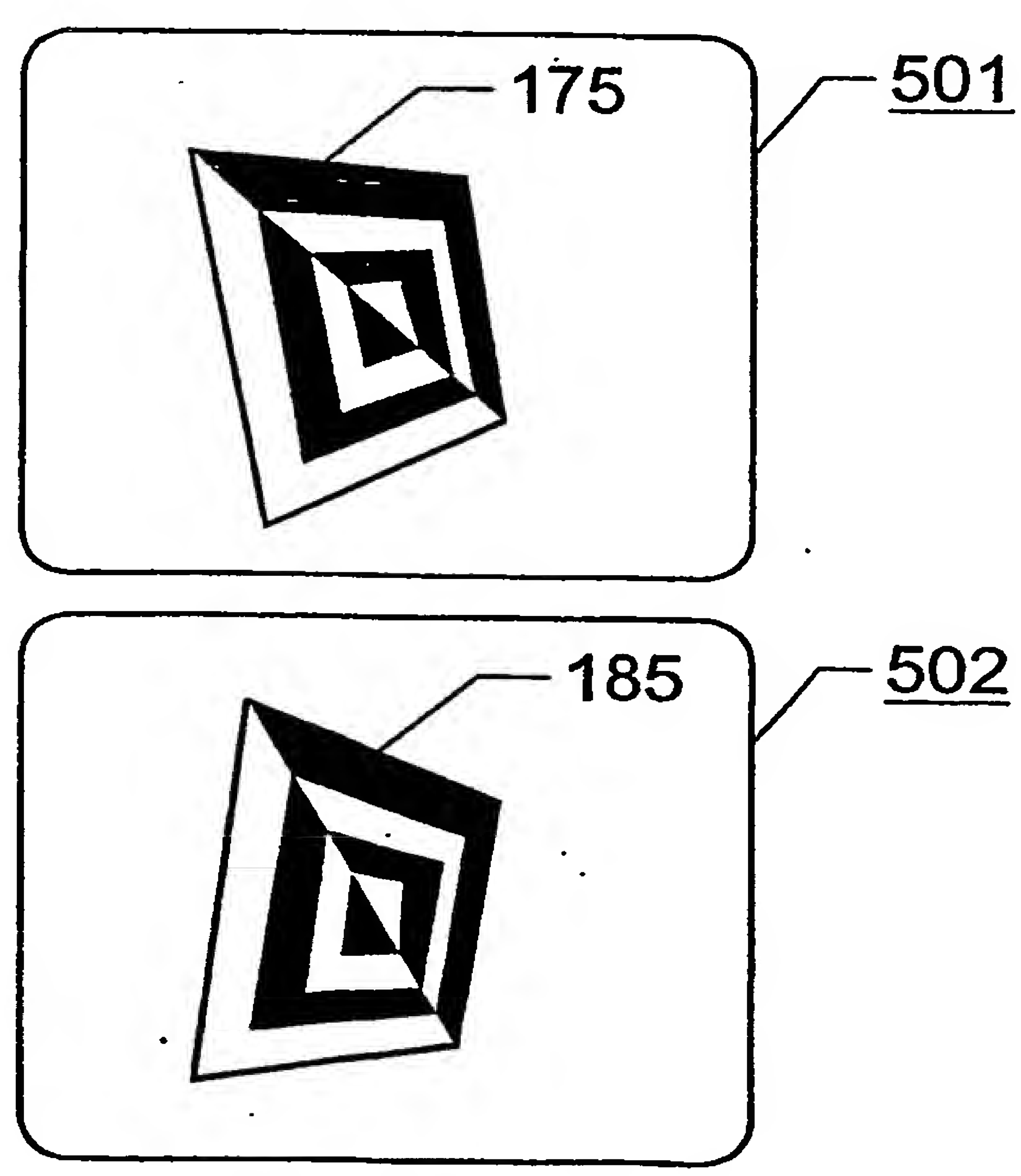


Fig. 5b

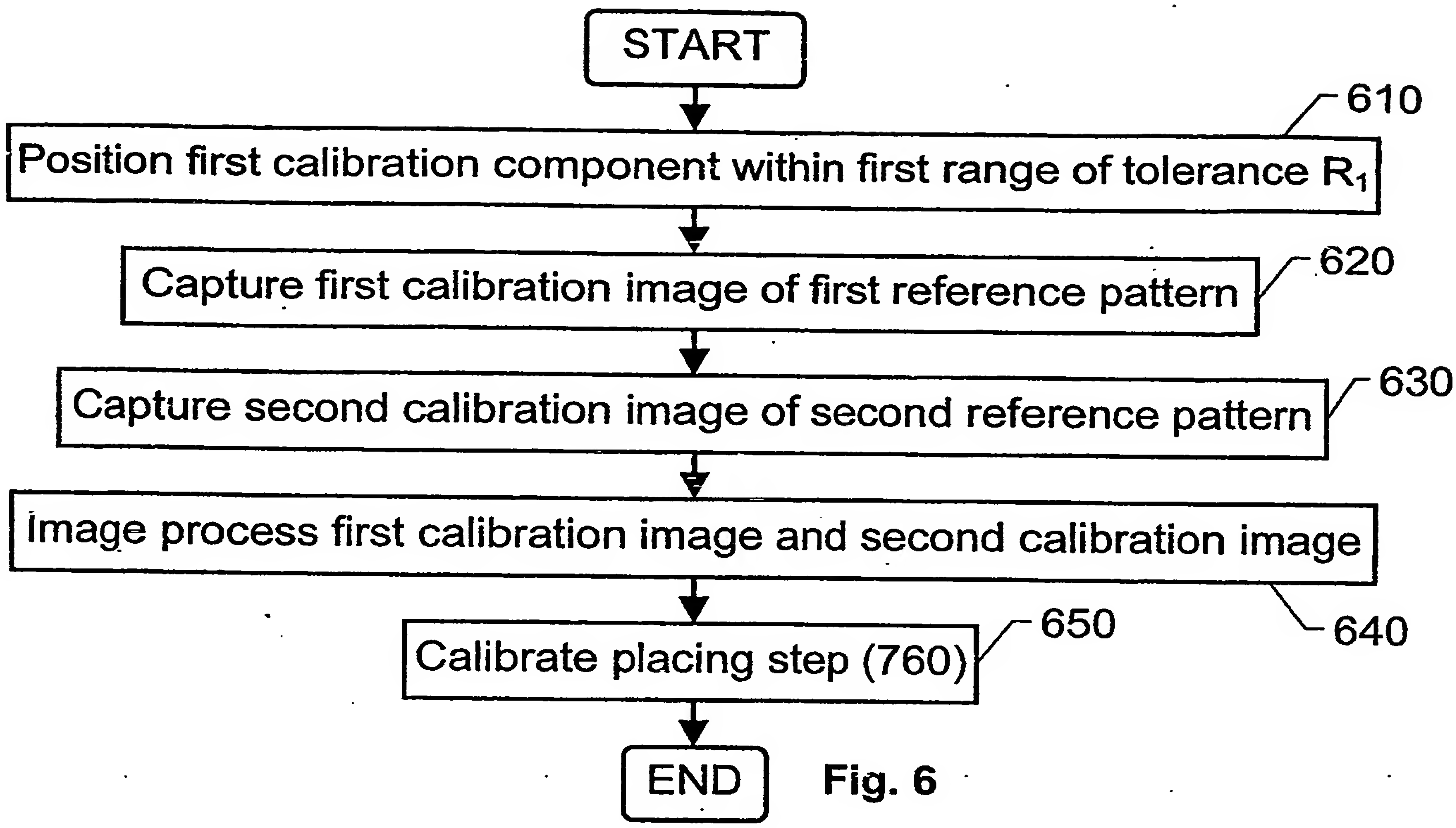

START
Position first calibration component within first range of tolerance R_1
610
Capture first calibration image of first reference pattern
620
Capture second calibration image of second reference pattern
630
Image process first calibration image and second calibration image
640
Calibrate placing step (760)
650
END

Fig. 6

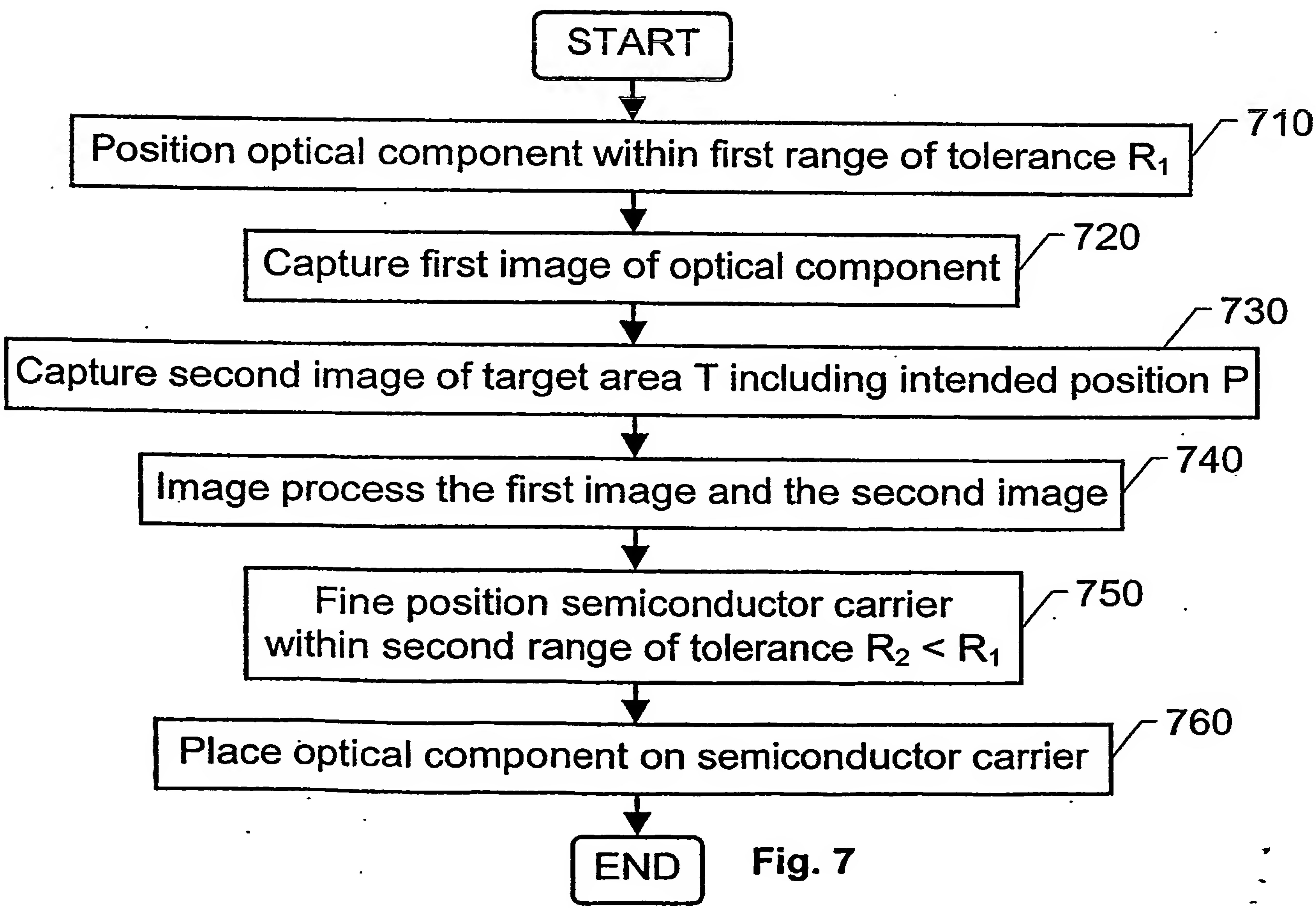

START
Position optical component within first range of tolerance R_1
710
Capture first image of optical component
720
Capture second image of target area T including intended position P
730
Image process the first image and the second image
740
Fine position semiconductor carrier
within second range of tolerance $R_2 < R_1$
750
Place optical component on semiconductor carrier
760
END

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 02/01636

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H01L 21/68, H05K 13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H01L, H05K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6043877 A (EGBERT F.A. LAND), 28 March 2000 (28.03.00), see whole document --	1-20
A	US 5880849 A (JOHANNES T.A. VAN DE VEN), 9 March 1999 (09.03.99), see whole document --	1-20
A	US 5185811 A (GREGORY E. BEERS ET AL), 9 February 1993 (09.02.93), see whole document --	1-20
A	EP 0931623 A1 (SHIN-ETSU HANDOTAI COMPANY LIMITED), 28 July 2000 (28.07.00), see whole document --	1-20

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 November 2002	15 -11- 2002
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Stig Edhborg/MN Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	PATENT ABSTRACTS OF JAPAN Vol. 016, no. 2 (M-1197) 7 January 1992 (1992-01-07) & JP 03 228591 A (CANON INC.) 9 October 1991 (1991-10-09) abstract -- --------	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

30/09/02

International application No.
PCT/SE 02/01636

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		EP 0809926 A,B	03/12/97
		JP 11502311 T	23/02/99
		WO 9722238 A	19/06/97
US 5185811 A	09/02/93	EP 0493105 A	01/07/92
		JP 2530955 B	04/09/96
		JP 6044360 A	18/02/94
EP 0931623 A1	28/07/00	JP 11207611 A	03/08/99
		US 6135854 A	24/10/00